THE UTILIZATION OF GPR DATA IN GIS

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Abstract

GPR (ground penetrating radar) is one of the most promising shallow subsurface detecting techniques. As a non-invasive tool providing a high-resolution image of shallow subsurface, it has been applied in mapping agricultural fields recently. In this practice, the variation in depth of soil layers with different characteristics can be determined, which is a primary factor affecting cropping potential. The application of GPR has improved the efficiency of soil survey considerably. Meanwhile it can be a kind of data source of GIS and provide much useful information that is difficult to obtain by other ways. In this paper, the processing of GPR data before using in GIS was discussed in detail. Then the way of GPR data management in GIS is proposed and the workflow of managing GPR data in GIS is given. Finally, the method of analyzing the influence factors of soil erosion using GIS, GPR data and other ancillary data was given. As a data source, GPR can provide information that can’t be gain by other means. The combination of GPR and GIS will make them more effective tools.

INTRODUCTION

GPR (ground penetrating radar) is a robust and noninvasive technique for in situ shallow subsurface measurement. It can provide profile information of soil layers and strata with high resolution, such as the variations of soil water content with depth or the thickness of soil layers and strata. Over the past years, GPR has been widely used in mapping and surveying of agricultural fields. The use of GPR for soil survey investigations was first demonstrated in Florida by Benson and Glaccum (1979) and Johnson et al. (1980). Since then, many additional GPR soil surveys have been conducted to increase the efficiency and the frequency of these works and to extend the depth of observation by Robert S. Freeland (1998), D.G.Paterson (2000) and Paulo Roberto Antunes Aranha (2002).

GPR provides a number of advantages over other methods. One advantage is that the scale of features resolvable using GPR can range from a few centimeters to tens or hundreds of meters using the selection of antennas available. Another distinct advantage is the ability of GPR to provide high-resolution continuous profiling of an area. It’s much easier to estimate the presence, depth, and lateral extent of soil map units using GPR, so it’s possible to make a high quality soil map. A final advantage is the higher efficiency of GPR than other methods. In this study, we aim to research the ways to combine GPR and GIS for more efficient usage of GPR data.
GPR PRINCIPLES

The fundamental principle of GPR can be described in terms of the transmission, scattering (reflection, refraction, diffraction, and resonance), and detection of electromagnetic waves propagating through the subsurface by using antennas located on the ground surface (Daniels, 1989). Common GPR systems use antennas with a broad frequency range (50MHz to 1GHz), and the frequency of the wave affects the resolution and depth of penetration. Antennas using high frequencies provide a higher resolution image of the near subsurface and have a shallower penetration depth, while antennas using low frequencies provide a poorer resolution image.

In a pulse echo, time-domain GPR system, an electromagnetic pulse radiated from the transmitter antenna propagates into the subsurface. If the wave encounters an interface between materials with an impedance contrast that is produced by changes in electrical properties of the material (for example, the interface between the soil and the bedrock), then some of the electromagnetic energy is reflected (scattered) back to the ground surface, while the remainder of its energy is transmitted downward through the interface. The electromagnetic energy that is reflected back to the ground surface is detected by the receiver antenna on the ground surface and recorded over a chosen time interval on the GPR system. The GPR recording for single position on the surface is called a trace. A recorded section of successive GPR traces along the ground surface is presented as a (two-way travel) time-distance plot of a GPR cross section. Figure 1 shows a GPR profile made over an agricultural field.

DATA PROCESSING BEFORE USAGE

GPR suffers from strong attenuation and dispersion from the subsurface material, so some processing of GPR data are necessary to extract useful information from it. The procedure consists of noise reduction, velocity analysis, stacking and migration.

Noise reduction

Ordinarily there are two kinds of noise in GPR data. One is high frequency noise that would be caused by the radar system. This noise can be removed by using a band-pass filter. Objects on the ground surface would cause another kind of noise. This noise shows a very high propagation velocity. In practice, the apparent velocities of subsurface-reflected waves are much slower. This kind of noise can be easily suppressed by two-dimensional f–k filtering. In f–k domain, this kind of noise is distributed around k=0 because the apparent velocity of the noise is very high.
Velocity analysis and velocity correction
The velocity analysis can be done on GPR data collected by common midpoint (CMP) method. The travel-time of a reflection in a CMP gather can be expressed by an equation that is a function of an antenna offset and velocities (Yilmaz, 1987). Therefore, a CMP data set can provide a velocity profile in the subsurface media by velocity analysis.

Stacking and migration
Stacking is to generate a single trace from n traces of GPR data. Stacking increases the energy of the reflected signals and decreases the energy of the noise, so the stacked profiles have an improved signal-to-noise ratio. Theoretically, the signal-to-noise ratio of the stacked profile is improved $\sqrt{n}$ times over the random noise when the number of traces of is n. Migration can improve the accuracy of spatial positioning. Figure 2(a) is a GPR profile before stacking and migration and Figure 2(b) is its result after stacking and migration.

APPLICATIONS OF GPR DATA IN GIS
GPR may be viewed as a kind of source of spatial data; so aided by the capability of GIS in management and analysis of spatial data, GPR data can be used more effectively and efficiently. In what follows, some feasible ways of utilize GPR data in GIS.

The format of GPR data is different from vector-graphs and images. It save the physical characteristics of electromagnetic waves (amplitude, frequency etc.), and ordinary GIS software can’t process it. So the management of GPR data can be managed in geo-database in two ways. One way is to save them like satellite imageries, but the amount of data to save is very large. Another way is to extract some information from the GPR data. In this way, the GPR data need preprocessing and extracting spatial information and statistical or geo-statistical information derived from these data in GPR software. The spatial information consists of the coordinate of GPR data and the spatial position of the interface between main soil layers. The statistical or geo-statistical information describes the whole feature of the data about velocity, absolution, amplitude, and so on. Using the coordinate of the GPR data can be denoted on a topographical map, the spatial position of the interface between main soil layers can be saved as elevations on related coordinate, and each interface should be saved independently. The statistical or geo-statistical information should be saved as attribute information linked with the coordinate of the GPR data. Figure 3 shows the whole workflow.

Aided by the capability of GIS in spatial analysis, GPR has bright prospects in soil erosion. Using elevation information of soil layers saved in GIS and digital topographical map, DEM of one of the soil layers or bedrock of study area can be generated as well as ground surface. Then the information such as soil depth of each layer and gradient of soil layers or
bedrock are easy to acquire. Other ancillary data consist of vegetation classes, precipitation and so on. All these data can be regard as influence factors to soil erosion and be input GIS software. In GIS software, each of these data is a single layer, and they are registered and overlay each other. By analyzing the relationship between soil erosion level and those influence factors, the influence coefficient of each influence factors can be identified. Because the influence of topographical characteristics of soil layers and bedrock are considered, the analysis is more comprehensive.

OUTLOOKS

GPR is non-invasive shallow subsurface detecting techniques with a high-resolution. It can be a kind of data source of GIS and provide much useful information that is difficult to obtain by other ways. So the efficient utilization GPR data in GIS is a considerable issue. This issue also has bright prospect in landslide analyzing and geological process monitoring.

REFERENCES


